System Thermal Considerations for AMD Athlon™ and AMD Duron™ Processors

Tom Dolbear

Senior Member of Technical Staff

Advanced Micro Devices, Inc.

Platform Engineering

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Outline

- Introduction
- Temperature budget
- Physical placement and keepouts
- Venting
- Acoustics
- Shock and vibration
- Power cycling testing
- System thermal test methodology
- Summary
- Future requirements

Power has increased in 5 years

- **Power = N*C*V^2 f**
- **Number of transistors has increased**
  - » 5 million --> 22 million
- **Gate length has been reduced**
  - » Gate oxide thickness has been reduced
  - » 0.35 um ---> 0.18um
- **Voltage has been reduced**
  - » 3.3V ---> 1.75V
- **Frequency increase of ~10x**
  - » 100MHz ---> 1000MHZ
- **Net increase in power of ~ 4-6X over five years**

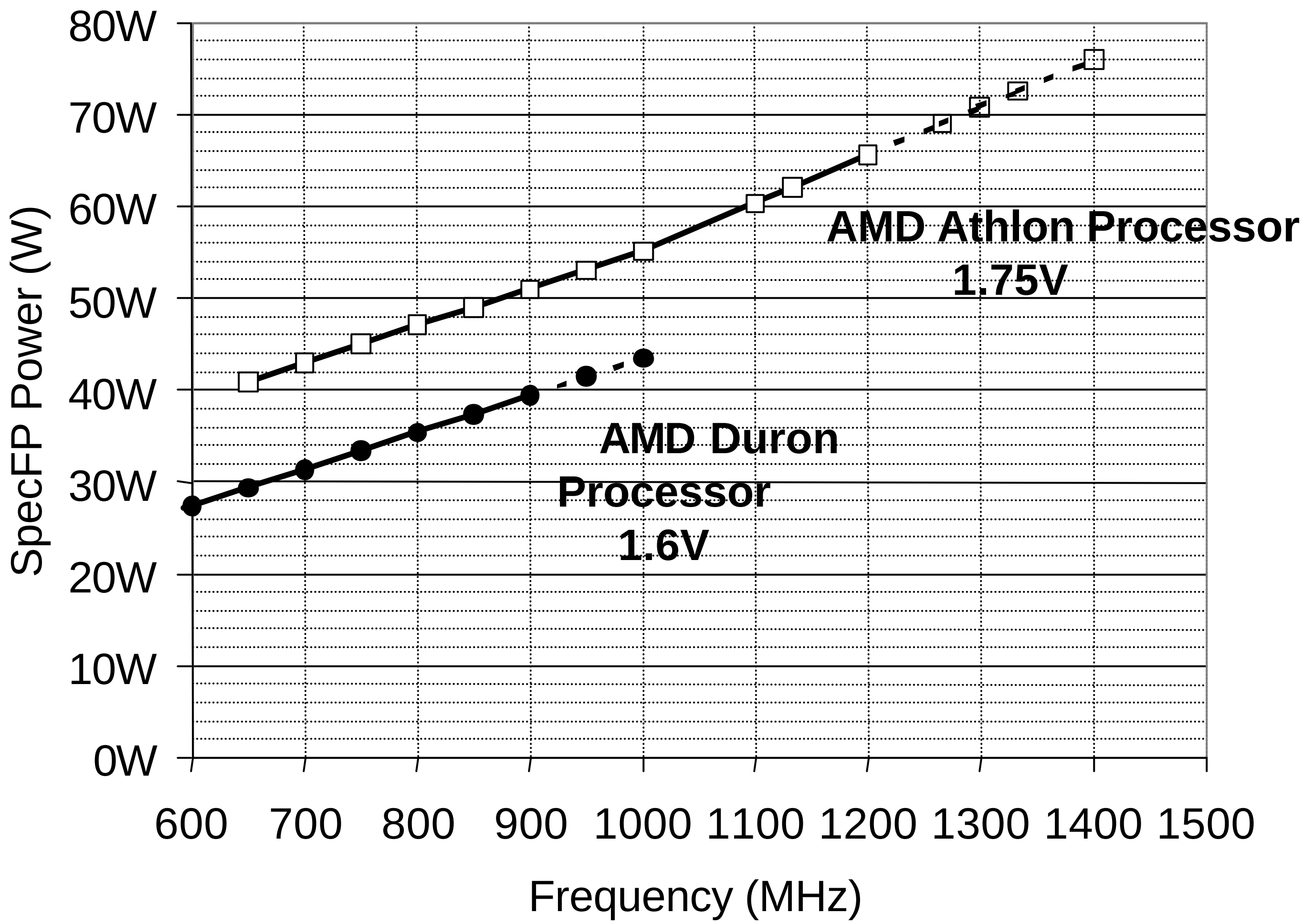
Temperature impacts performance and reliability

- **Performance of processor governed by**
  - ? architecture & circuit implementation
  - ? process technology
  - ? voltage
  - ? temperature
  - ? frequency
- **Reliability**
  - ? circuit implementation
  - ? process technology
  - ? temperature

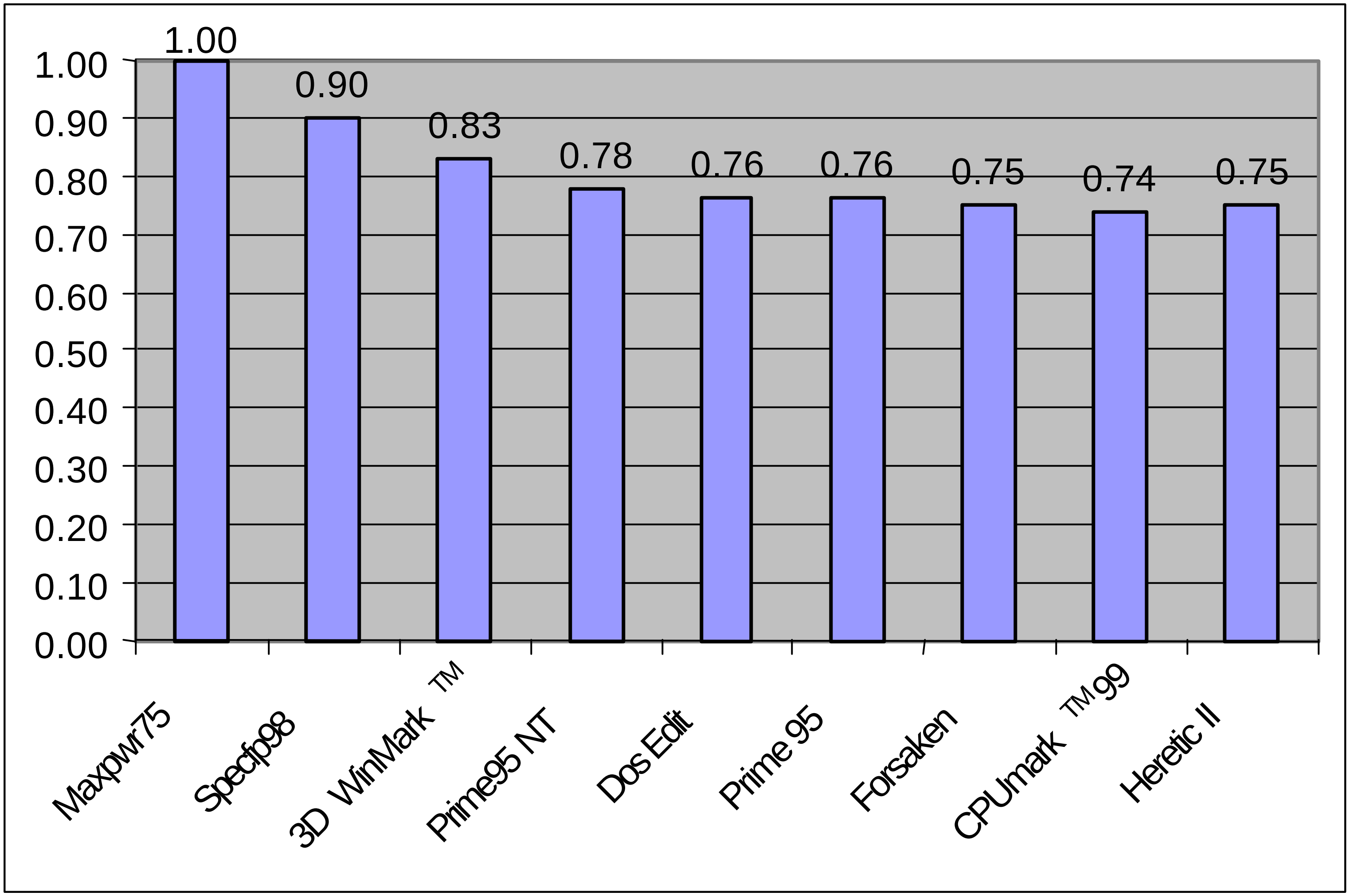
System Form Factors

- **Desktop (focus of this presentation)**
  - ? ATX
  - ? uATX
  - ? mini-ATX
- **Small form factor**
  - ? emerging market especially in Japan
- **Mobile**
  - ? All in one or desktop replacements
  - ? thin & light
- **Dual processor systems**
  - ? workstation & 1U implementations

AMD Athlon™ and AMD Duron™ Processor Power



Power Depends on Software...



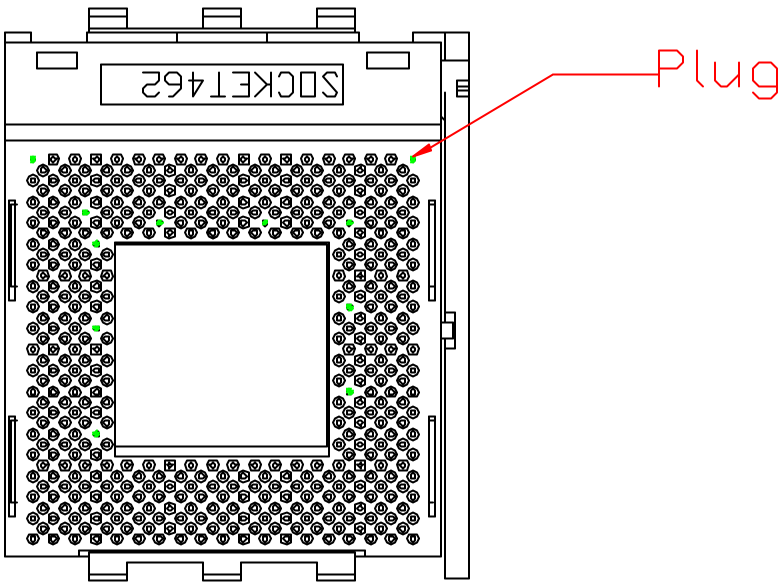
Temperature Budget for AMD Athlon™ and AMD Duron™ Processors

• Processor:	AMD Athlon	AMD Duron
• Max die temperature:	90 or 95 °C	90 °C
• Max external ambient:	35 °C	35 °C
• Air temperature rise:	7 °C	12 °C
• Local CPU ambient:	42 °C	47 °C
• Temperature budget:	48 or 53 °C	43 °C

Important: Must design system for future speed grades.

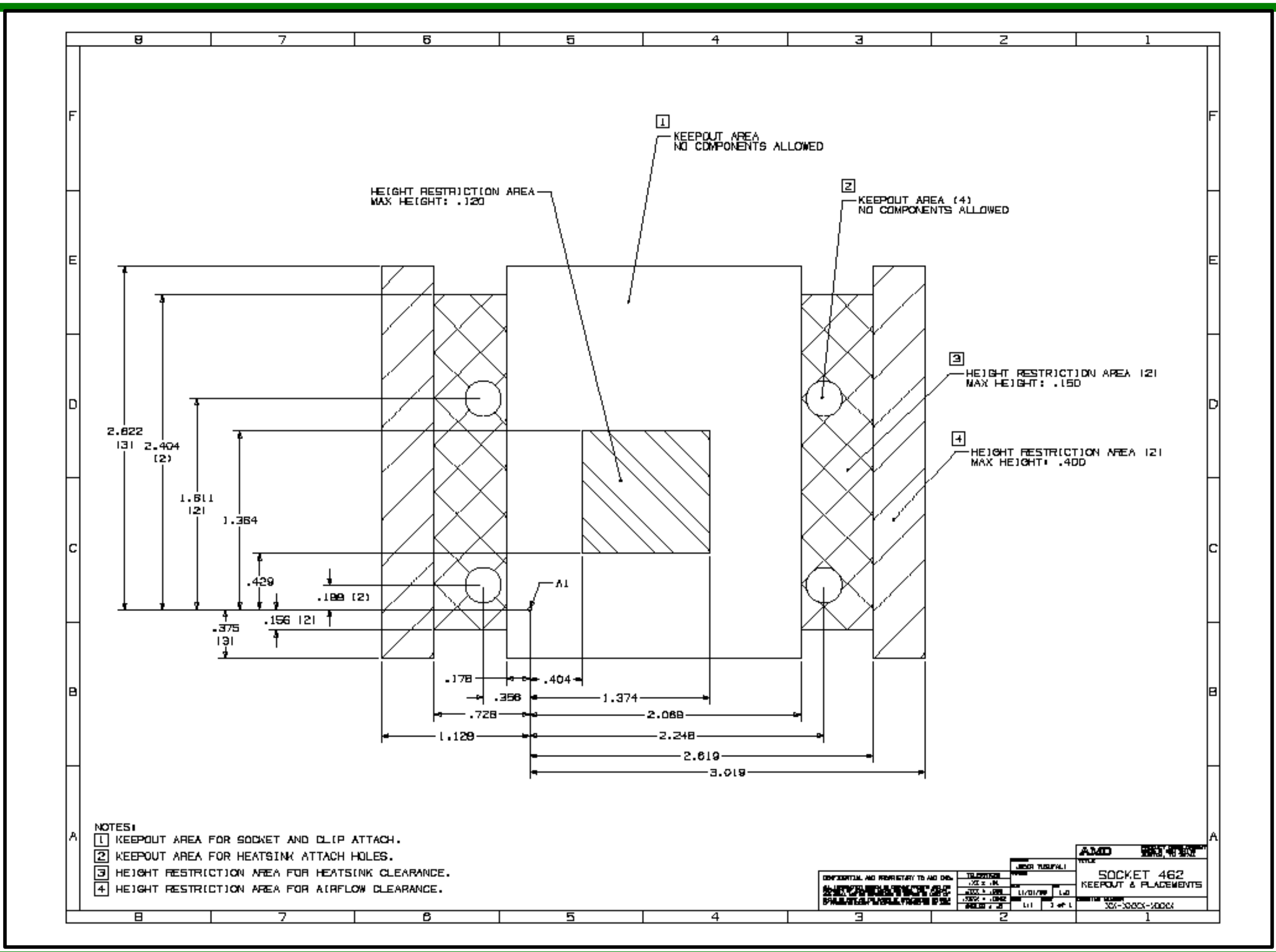
AMD Athlon™ Processor Socket 462

- **Designed for AMD Athlon processor**
- **Three heat sink clip tabs are provided**
  - ? 300 gm limit for heat sink mass
  - ? Shear testing of socket clip tabs indicates that sockets will support this
- **Vendor list**
  - ? Foxconn
  - ? FCI/Berg
  - ? Molex
  - ? Otax
  - ? Thomas & Betts



Platform Conference

Keepout and Height Restrictions



Keepout and Height Restrictions

- **Maximum heat sink footprint is 60mm x80mm**
  - ? overhangs socket footprint
  - ? required for max power over the product life
- **Heat sink will be clipped to the socket**
  - ? by a single clip for low mass heat sinks
  - ? by dual clips for high mass heat sinks
- **Heat sink mass of upto 300gm will be supported**
- **Hole pattern defined for mounting heat sink to motherboard or motherboard to chassis.**
  - ? Will be utilized if needed to meet shock and vibration requirements

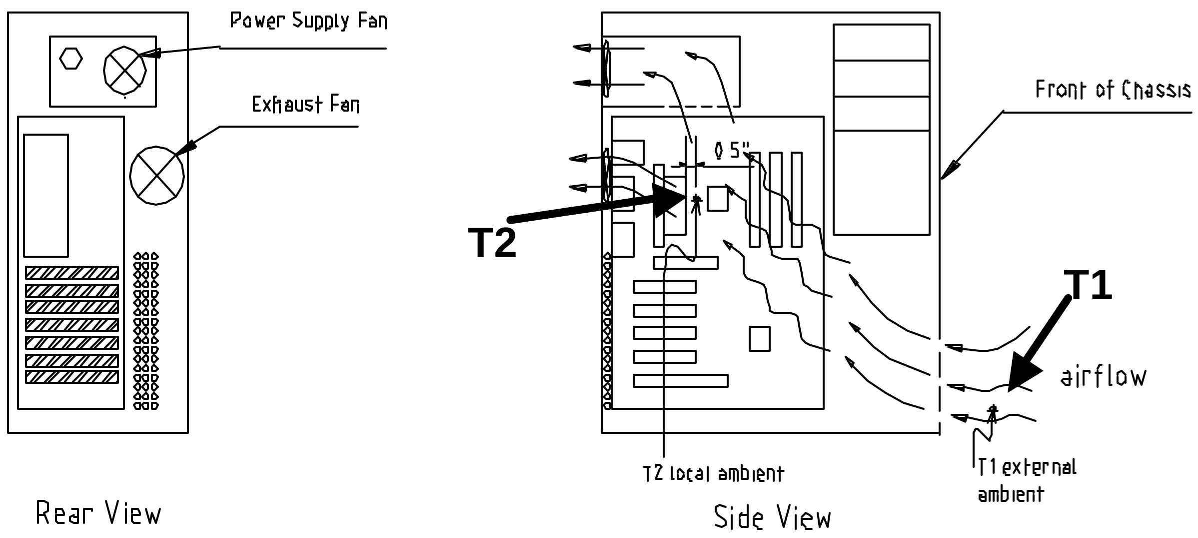
Venting Guidelines

Venting guidelines

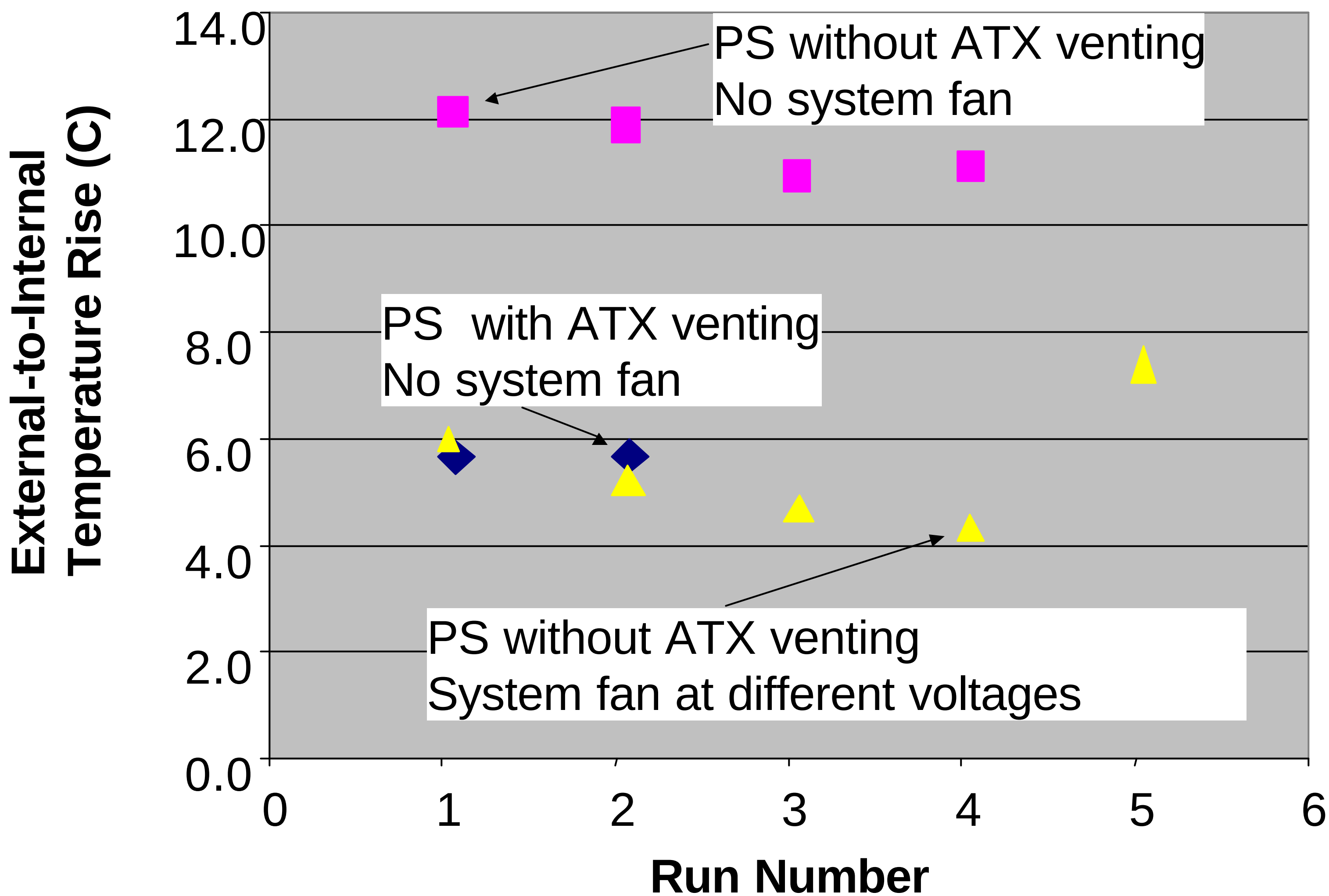
- **Maintain system temperature rise to a minimum**
  - ? AMD Athlon™ systems design rule │ 7 °C
  - ? AMD Duron™ systems design rule │ 12 °C
- **Evaluate impact of power supply venting on air temperature rise**
- **Consider impact of different power supply placements on thermal performance**
- **Minimize system pressure drop to increase flow through chassis**
- **Plan ahead for use of system fans**

Maintain less than a 7 °C system rise

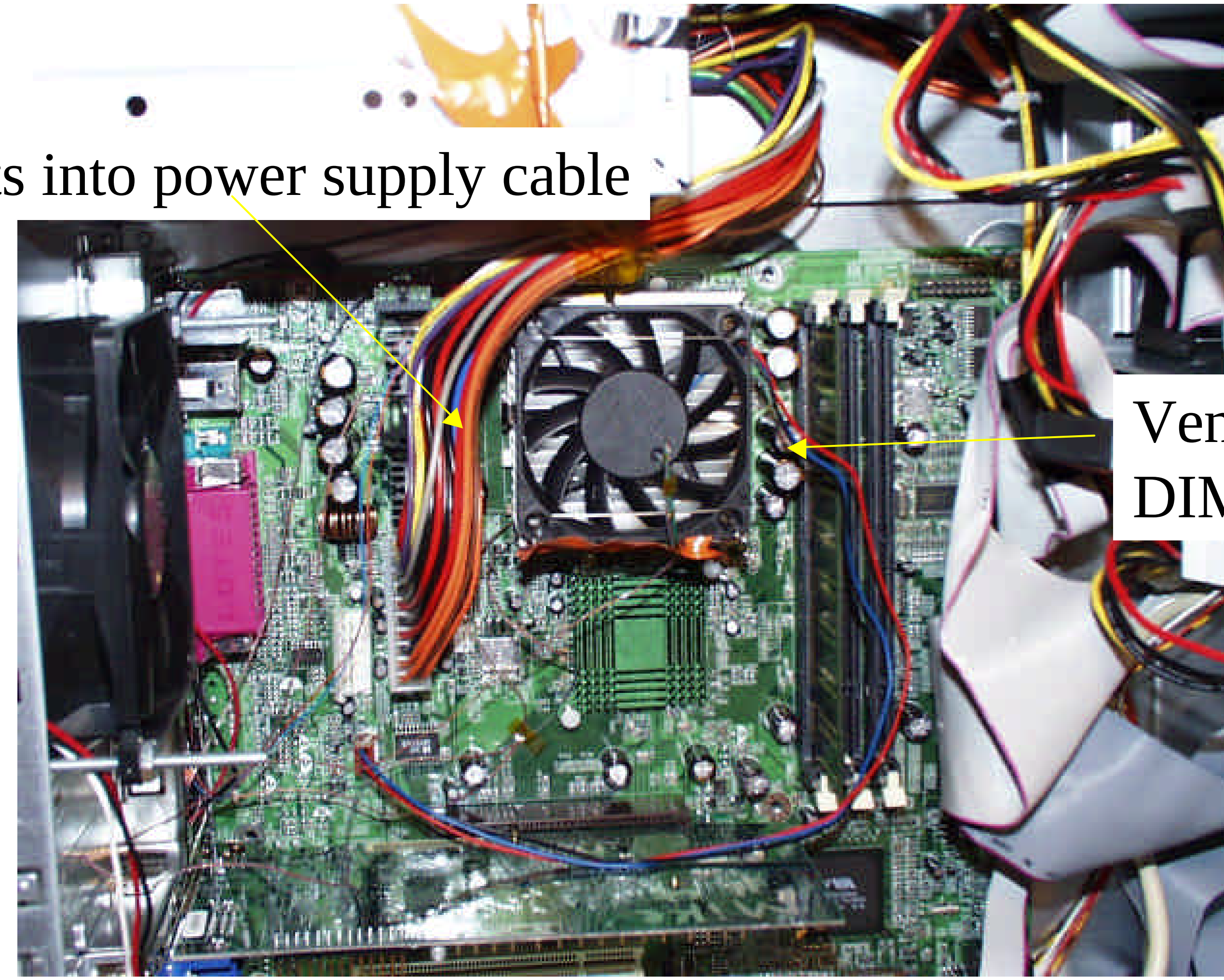
- *Qualitative Rules for Proper Cooling*
  - Use Exhaust Rear Chassis fan. Suggested size of 80 millimeters.
  - Use a power supply with ATX-style venting in the processor region.
  - Maintain a ?T ? 7ºC.
    - ?T = T2 - T1
    - ?T ? 7ºC to ensure proper cooling



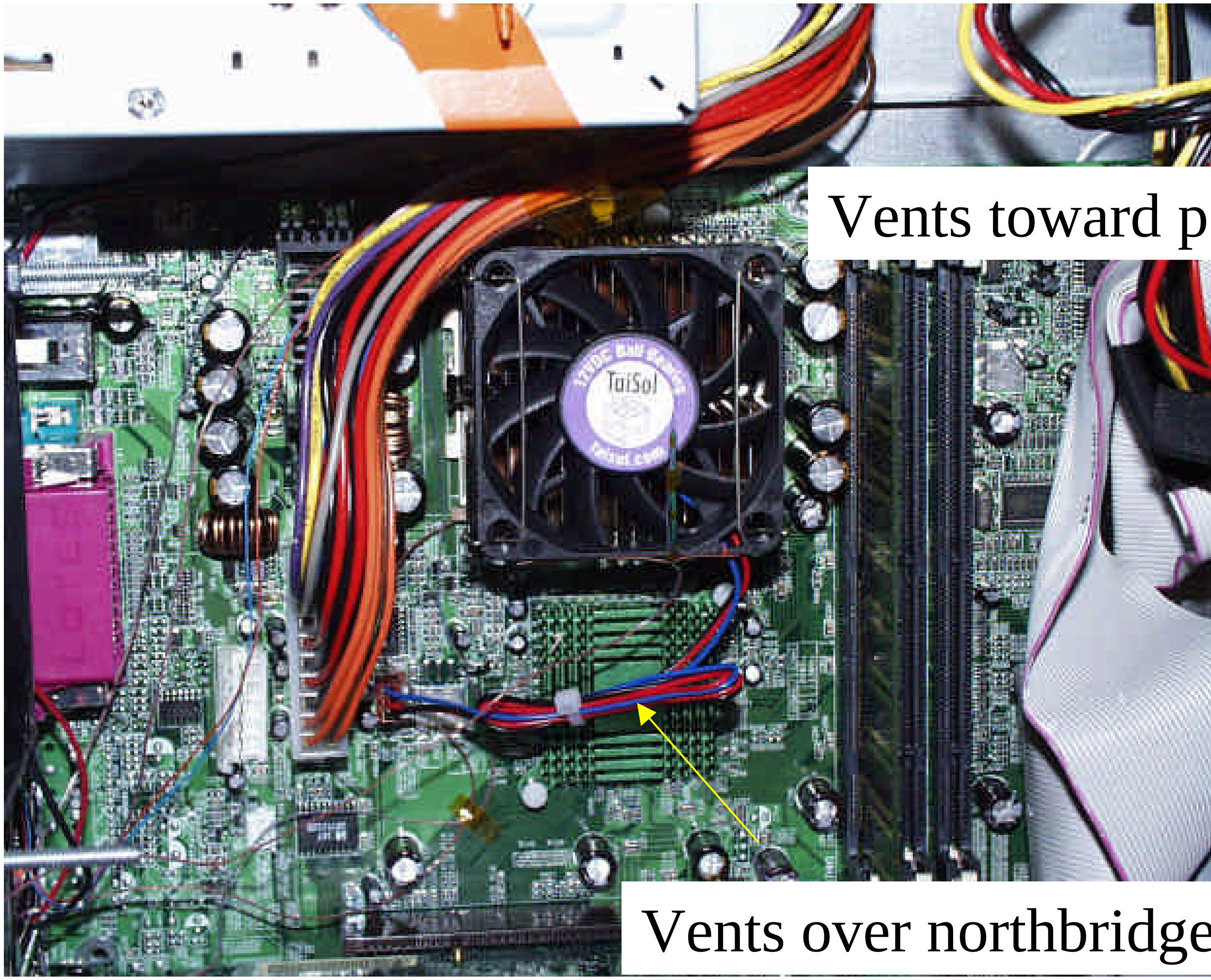
Impact of Power Supply Venting



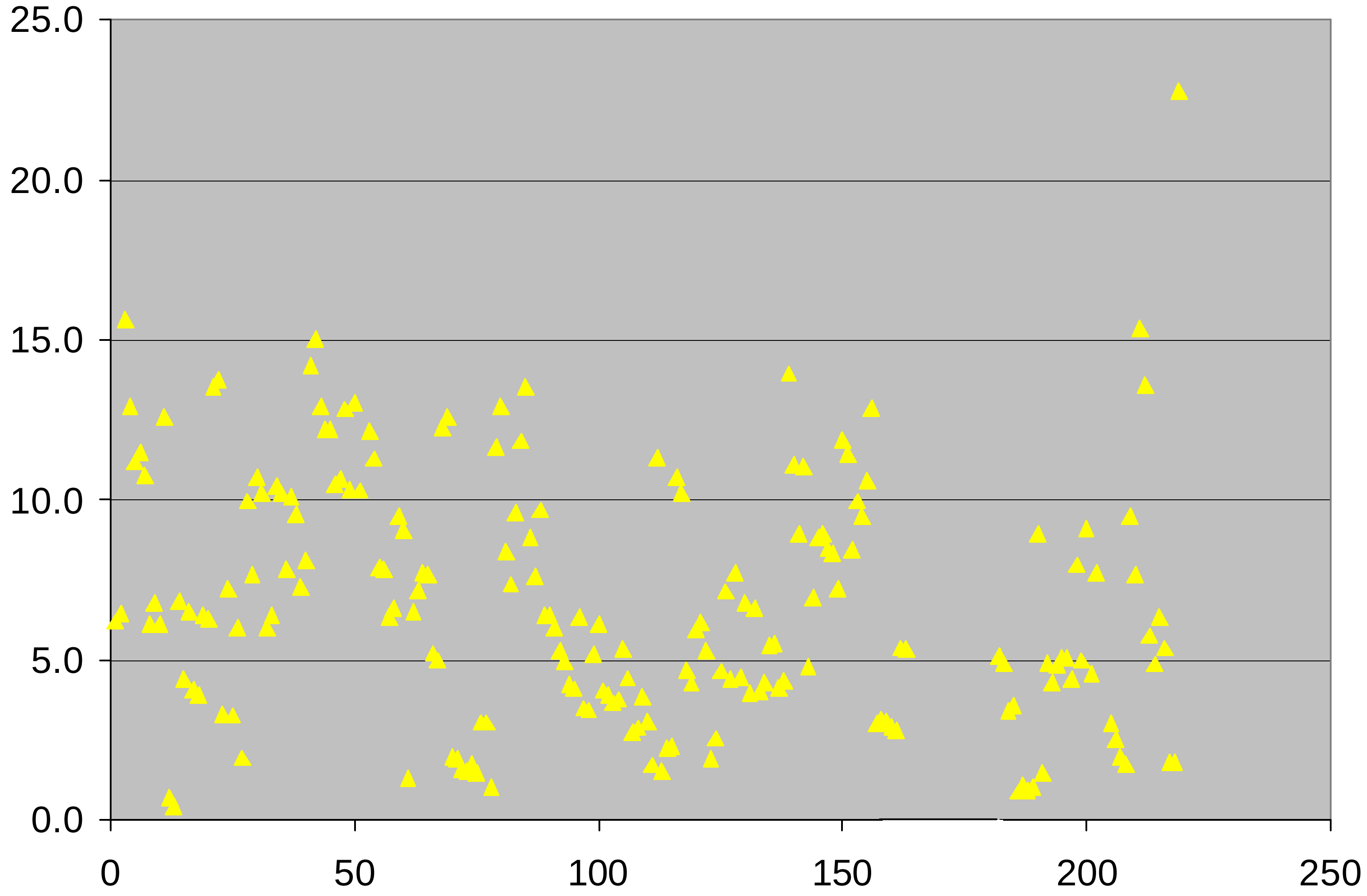
Example system placement



Example system placement



Database of system temperature rise



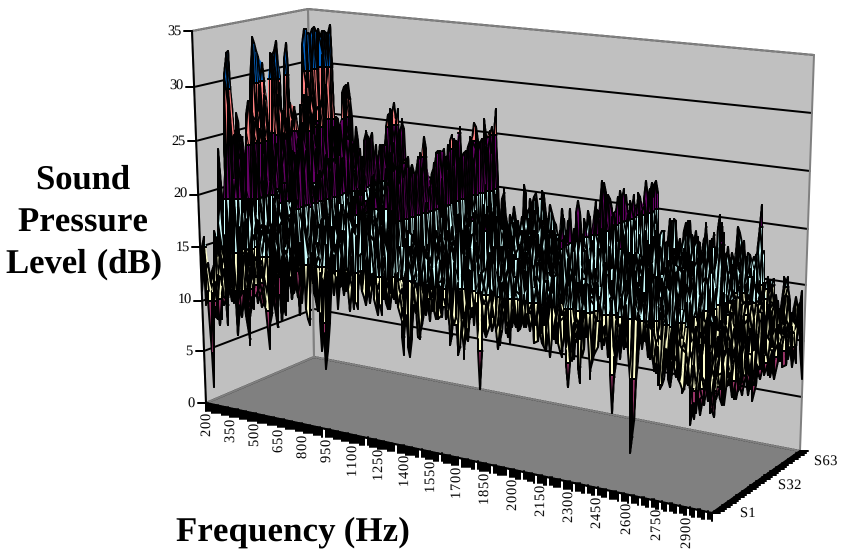
Acoustic Guidelines

Acoustic design guidelines

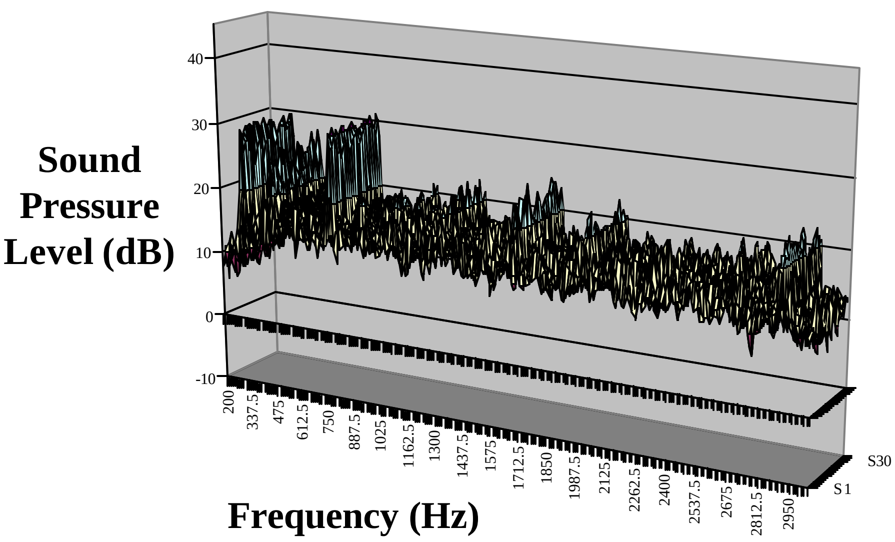
- **Efficient thermal design**
  - ? Choose high performance interface materials
  - ? Design high performance heat sink
- **Use largest size fan and slowest rpm that meets thermal requirements**
- **Profile heat sink for discrete tones or modulation**
- **Implement speed control of fans in system**
  - ? Especially effective in office environments
    - » CPU fan
    - » System fan
    - » Power supply fan

Test sound power as well as tones

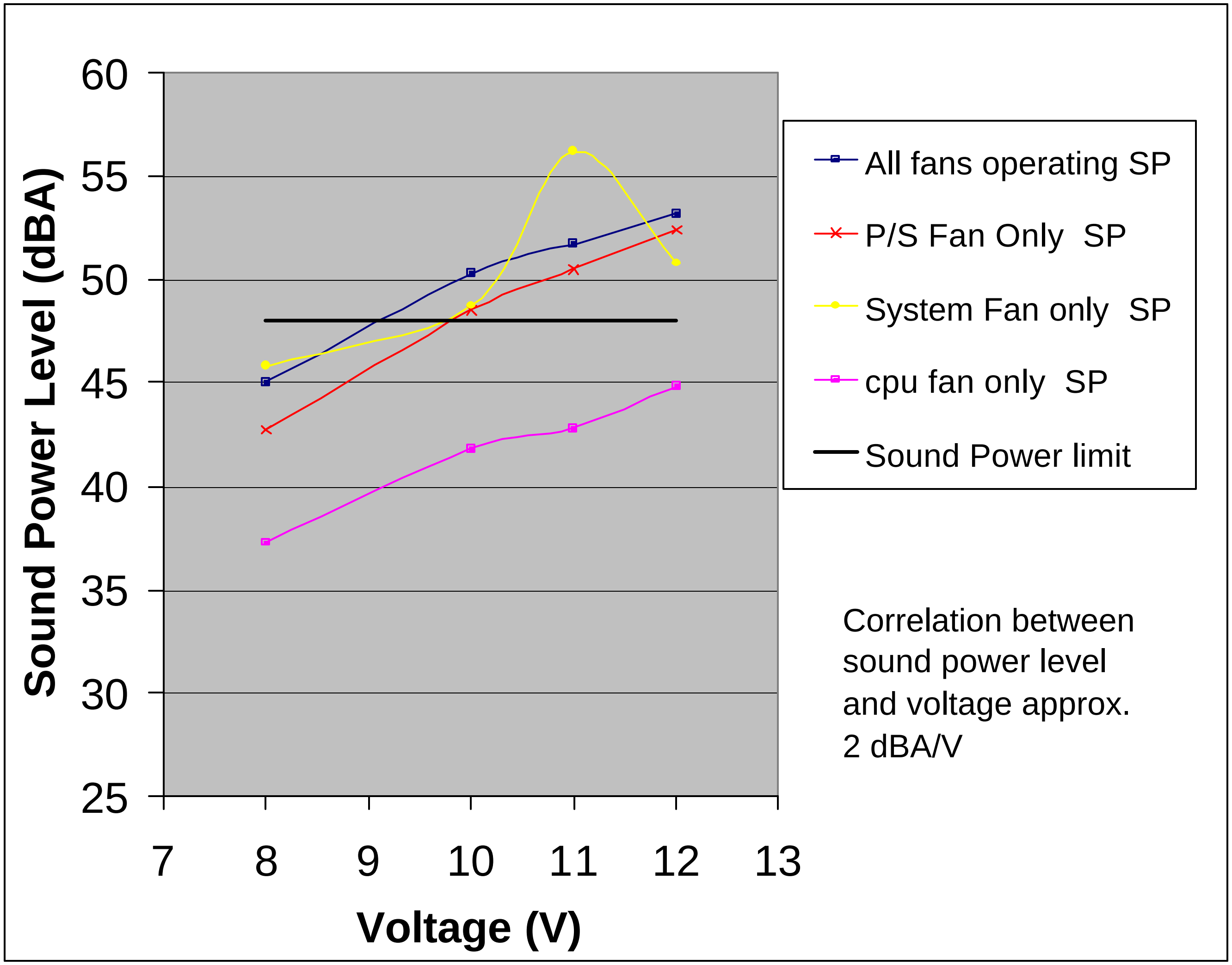
No offset



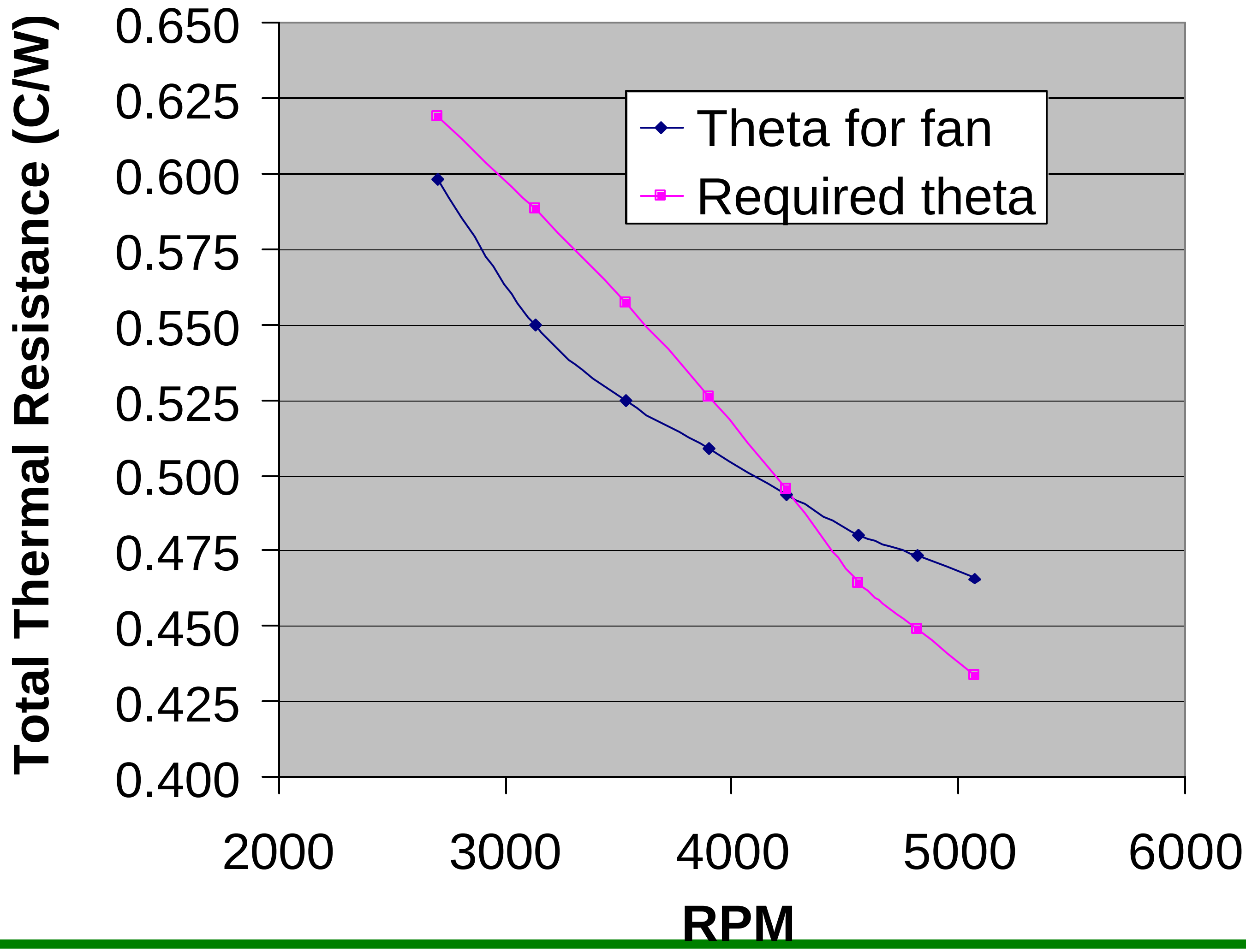
Veritcal offset of Fan to heat sink of 6 mm



Impact of Fan Voltage on Sound Power

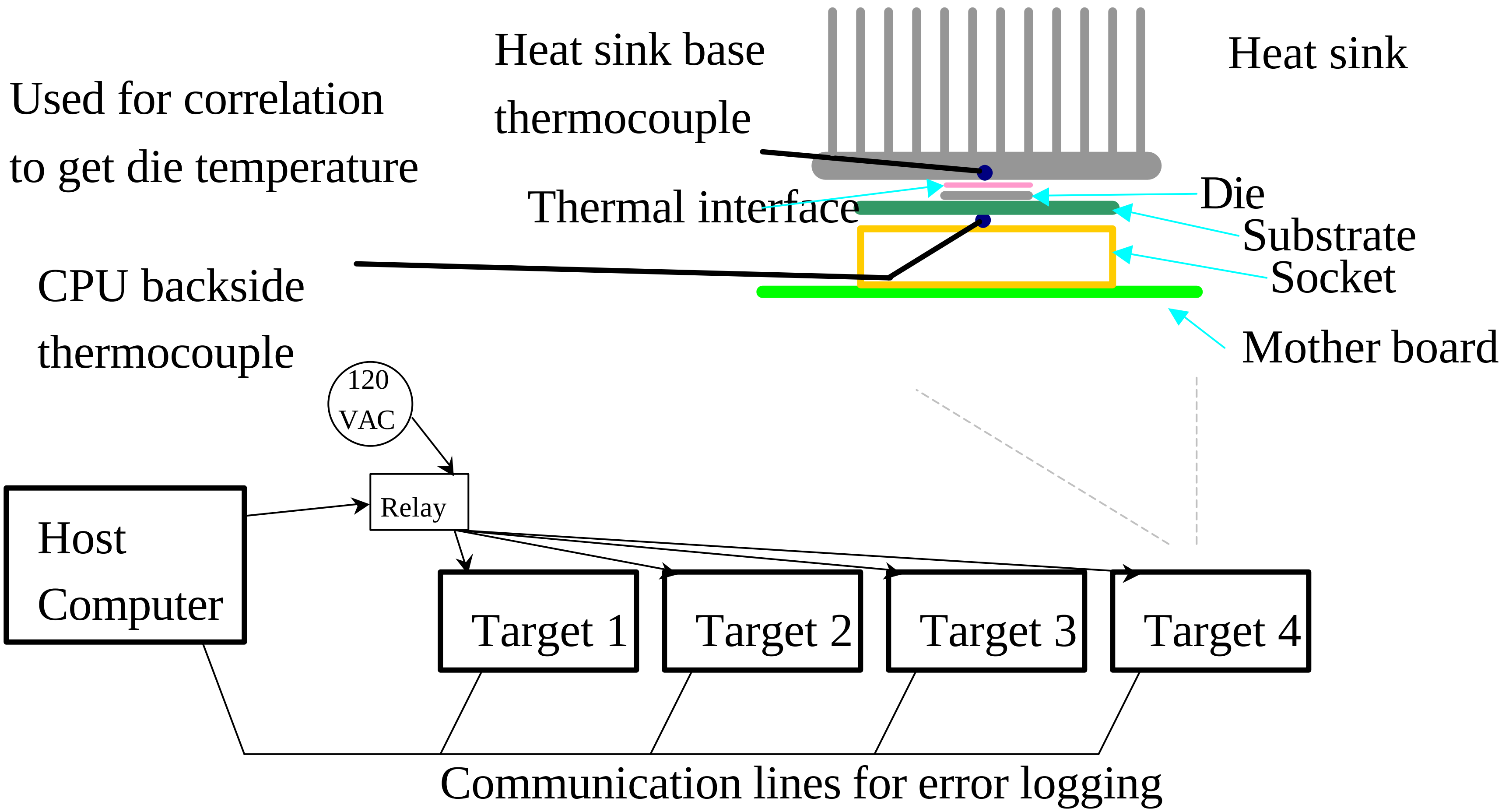


Total thermal resistance vs. RPM

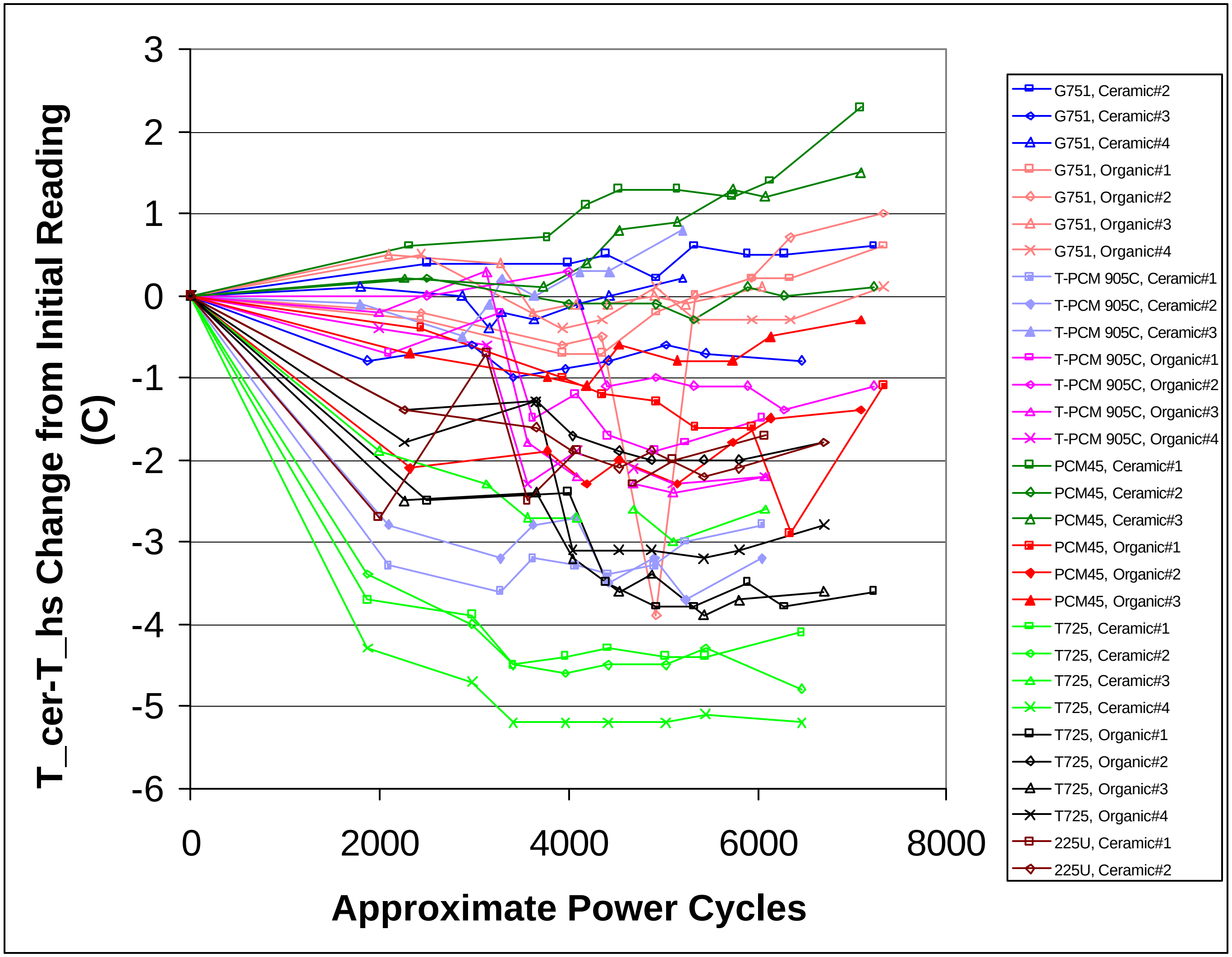


Power cycling

Schematic of Power Cycling Apparatus



Final Read-point Power Cycling Data

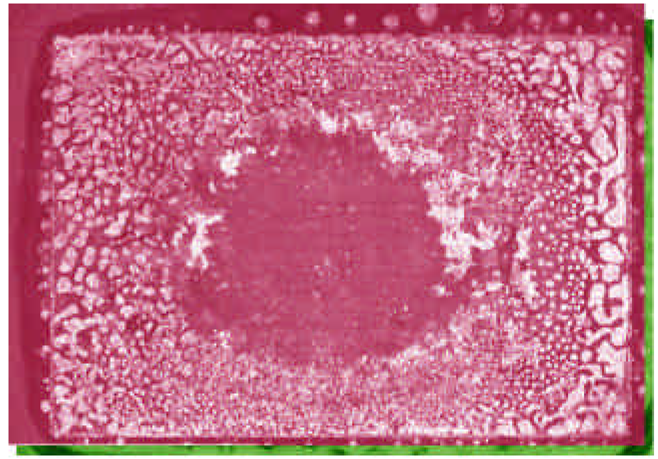


Voiding Analysis after Cycling

Die side

Dark areas are interface material

Heat sink side



Transparent overlay of heat sink on die

- Interface material patterns match
- Material was not pumped out
- Voiding negligible

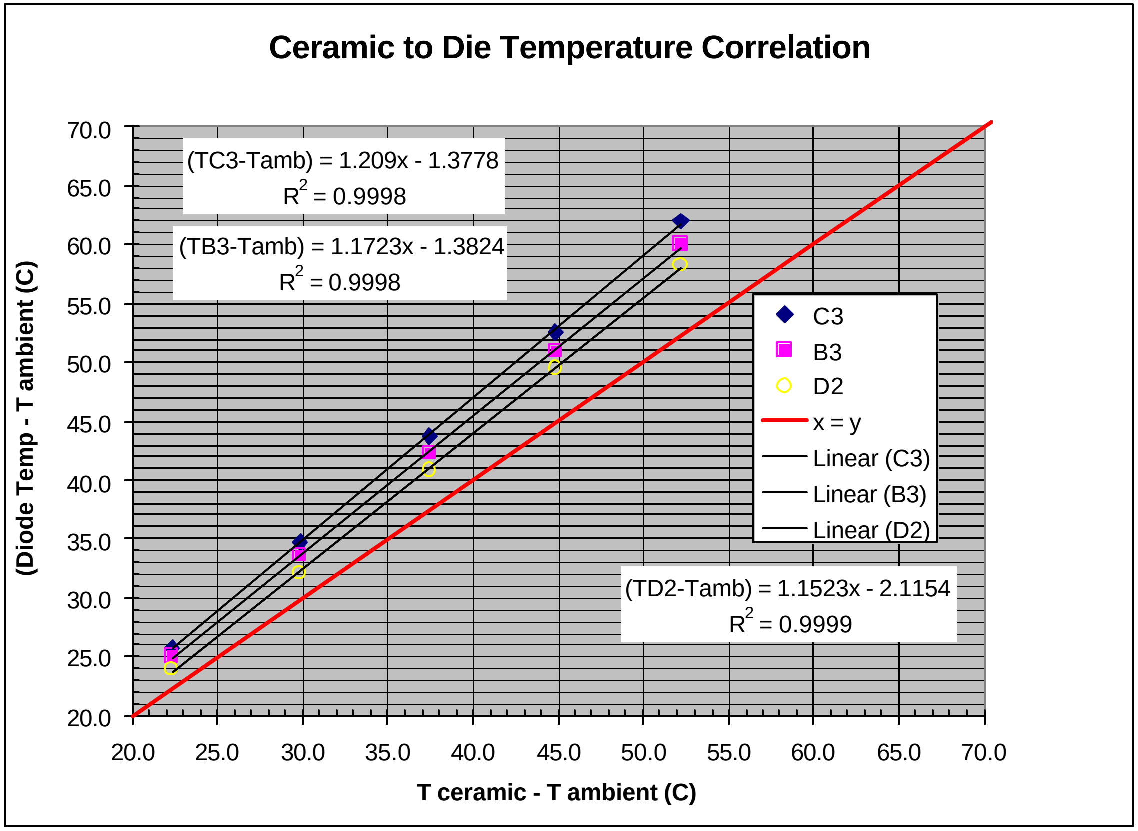
Thermal Metrology Methods

- Method # 1: Indirect measurement method
- Method # 2: On-die temperature diode measurement method

Method #1 Indirect method

- **Measure backside ceramic temperature**
- **Use correlation of backside ceramic temperature to die temperature based on measurements on thermal test vehicle.**
  - » Correlation relatively insensitive to the type of clip used.
  - » Thermocouple is centered on die area on back of silicon. Attached by taping to back of surface and run along ceramic.
- **Measure 8 -10 different set-ups to get feeling for variability of interface**

Correlation for Indirect Method



Typical residual

+/- 2C for centered clip

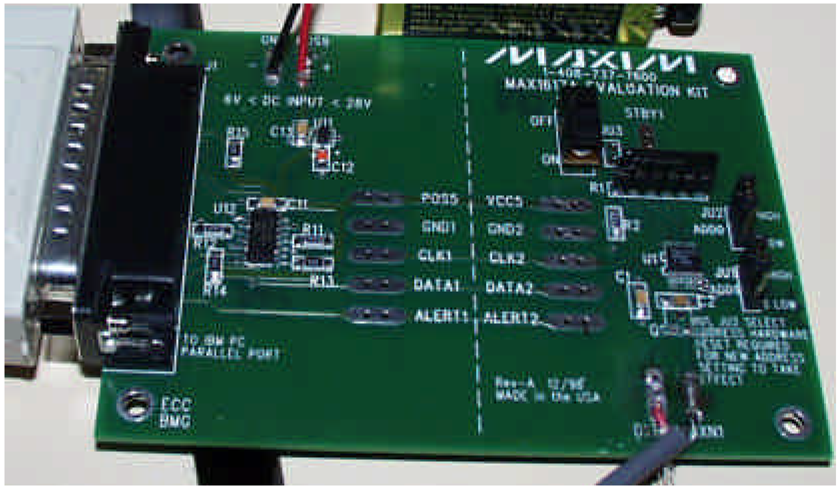
- **Measurements performed for one interface attachment to a thermal test vehicle**
  - ? Natural convection environment
- **Power varied to create correlation**
- **Chomerics T725 used as the interface material**
- **Asymmetric single point clip used for loading.**
- **C3 and B3 are centered diode locations**
- **D2 is on the edge toward the CAM.**

Using the On-Die Temperature Diode

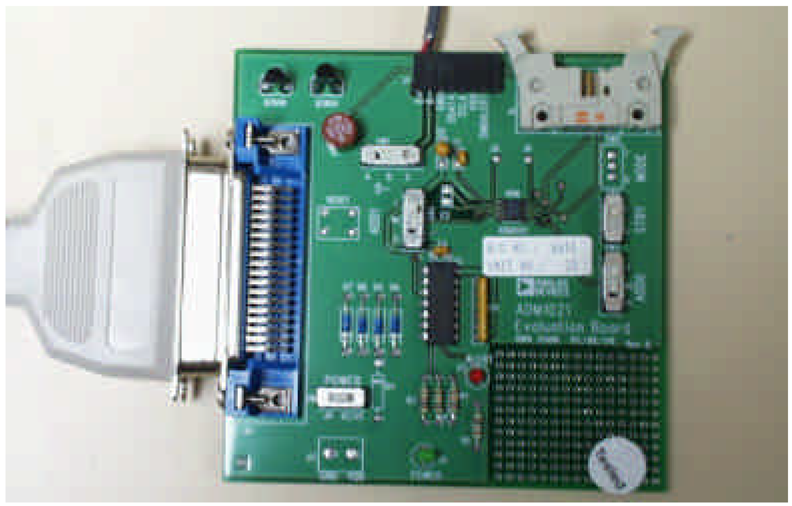
- **On-chip diode on Palomino and Morgan cores.**
- **Evaluation kits successful used with on-die diode:**
  - » Maxim 1617A (www.maxim-ic.com)
  - » Analog Devices 1021A (www.analog.com).
- **For verification, attach a thermocouple to the backside of the ceramic beneath the die.**
  - ? The thermocouple temperature should increase with power at a similar rate as the diode temperature.

Evaluation Temperature Sensor Kits

- **Maxim 1617A Evaluation Kit**

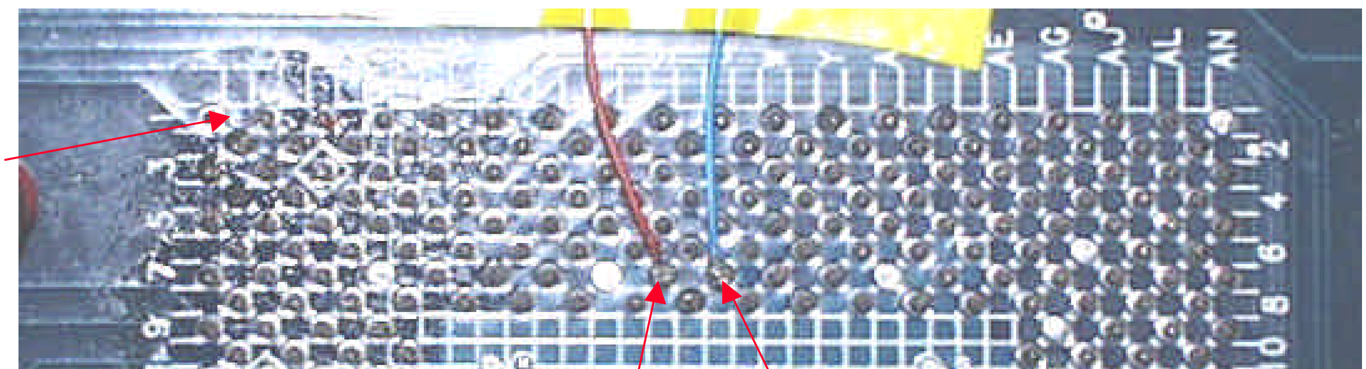


- **Analog 1021A Evaluation Kit**



Connect to the Diode

- **Attach temperature sense wires to the socket pins corresponding to the temperature diode (S7 and U7).**
- **Use high quality shielded wire.**
  - ? High resistance can affect the accuracy of measurement.
  - ? Wires should be shielded to prevent electro-magnetic interference from affecting the measurement.

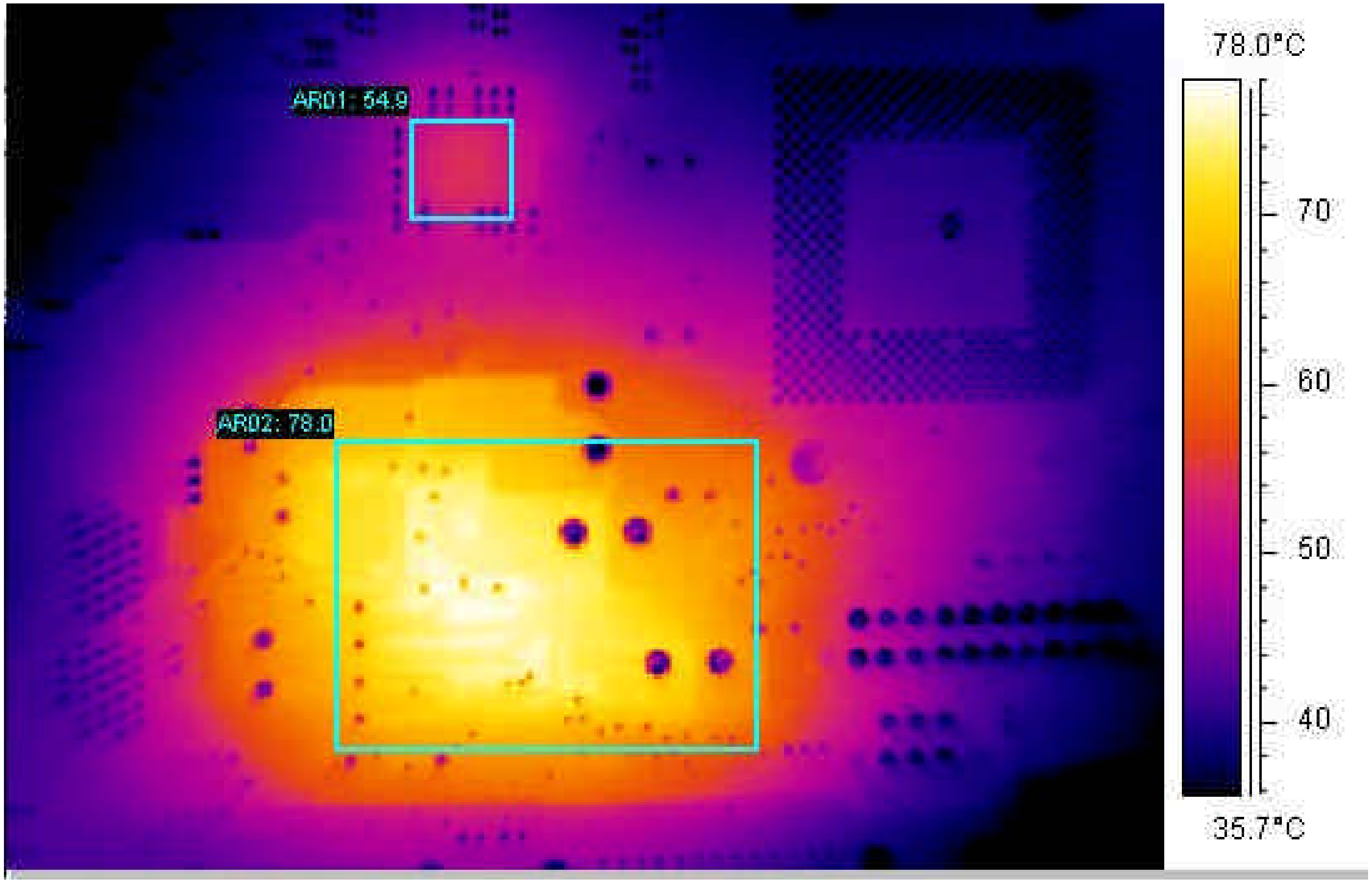


System Thermal Testing Methodology

Requirements

- **Die temperature should not exceed 90°C or 95°C.**
  - ? In a 35°C external ambient environment
  - ? At maximum thermal power.
  - ? Margin factored in on a customer-by-customer basis.
    - » altitude effects, different software, or external ambients.
- **Other components should not exceed their temperature specifications.**
  - ? Northbridge, power FETs, hard drives, etc.
- **Important: Test to specification not to a single part.**

IR Image of regulator region



Test Methodology

- **Measurements taken at room temperature.**
  - Temperature controlled fans in power supply are run with voltage at 35ºC setting.
- **Maxtherm software used to power processor.**
- **Thermocouples placed at following locations:**
  - Back of ceramic of PGA package of processor
    - See other application note for details on how to perform this measurement.
  - CPU Heat Sink Base (HS base)
  - CPU Ambient
  - FET Case
  - Under Motherboard @ Northbridge
  - Power Supply Exhaust
  - System Fan Exhaust (if applicable)
  - External Ambient
- **Vcc core feedback monitored.**

Test Methodology

- **Power supply fan voltage is monitored or set at voltage it would run at maximum external ambient temperature.**
- **Determination of processor power consumption:**
  - ? Processor placed in modified motherboard used for measuring power.
  - ? Vcc feedback voltage set to match that measured during thermal test.
    - » Current readout measured.
  - ? Maxtherm used to run test.
  - ? Power measured at close to same temperature of test.
  - ? Vcc Voltage x Current = Power used in spreadsheet.

Data Analysis

- **Room temperature data extrapolated to 35°C.**
- **Die temperature calculated using following correlation:**
  $(T_{die}-T_{amb})=1.209*(T_{ceramic}-T_{amb})-1.3778$
- **? $_{js}$ and ? $_{sa}$ calculated.**
- **Maximum Allowable Power (MAP) at 35°C calculated:**
  $MAP=(90^{o}C-T_{amb})/\ ?_{ja}$
- **Projected Die Temperature calculated:**
  T_{die}= Power(from MTP table)* ? $_{ja}+T_{amb}$

Data Analysis

- **MAP compared to Maximum Thermal Power (MTP).**
- **Example:**
  - ? MAP = 54W
  - ? From table, maximum frequency support = 1000MHz.
- **Max thermal power represents + 3sigma power dissipation of product at a given frequency and voltage.**

MTP Table:

	AMD Athlon™ 1.75 V
frequency	Max Thermal power:
D/C power	9
650	36.1
700	38.3
750	40.5
800	42.6
850	44.8
900	49.1
950	51.4
1000	51.0
1100	55.3
1200	59.6
1300	63.9
1400	68.2
1500	72.5

54W surpasses 1.0GHz, but is not enough for 1.1GHz.

Interpretation of spreadsheet data

Current from power measurement unit

max allowable die temp = 90.0 C

Vcc core feedback

Current: 30.1 A
Voltage: 1.80 V

Power: 54.1 W

	Under Ceramic	H/S base	CPU ambient	P/S exhaust	External ambient	Ext-Int Rise
test	64.1	53.6	30.2	35.8	24.4	5.9
@ 35C	74.8	64.2	40.9	46.4	35.0	

Average of raw data (obtained at room temp).

Data extrapolated to 35ºC external ambient

Die temp= (Tdie-Tamb) = 1.209* (Tceramic-Tamb) -1.3778 (from correlation data)

Die temp (@35C amb)= 80.5 C
theta js = 0.300 C/W
theta sink-cpu amb= 0.432 C/W
theta ja = 0.732 C/W
maxpower @ 35C amb: 67.2 W

Calculated using power number above.

Compared against Maximum Thermal Power chart to determine frequency support

	Frequency Support													
Processor	600	650	700	750	800	850	900	950	1000	1100	1200	1300	1400	1500
TB cs50 @1.75	X	X	X	X	X	X	X	X	X	X	X	X	.	.
SF @ 1.6	X	X	X	X	X	X	X	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Projected Die Temperatures (Max allowable temp = 90°C)													
Frequency (MHz)	600	650	700	750	800	850	900	950	1000	1100	1200	1300	1400	1500
TB @1.75	N/A	67.3	68.9	70.5	72.0	73.6	76.8	78.4	78.2	81.3	84.5	87.6	90.8	93.9
SF @ 1.6	62.1	63.5	64.7	66.5	67.9	69.4	70.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

'X' indicates pass at this frequency, '.' indicates that the part is projected to be out of spec. at this frequency

Summary

- Introduction
- Temperature budget
- Physical placement and keepouts
- Venting
- Acoustics
- Shock and vibration
- Power cycling testing
- System thermal test methodology

Reference Documents

- PID# 23792 AMD Athlon^{TM} Processor PGA Datasheet (Rev. G, 1029/00)
- PID# 90020 AMD Athlon^{TM} and AMD Duron^{TM} Processor Socket 462 Design Guide (Rev. C, 8/1/00)
- PID# 24363 Motherboard PGA Design Guide (Rev. A, 10/11/00)
- PID# 90031 AMD Athlon^{TM} Processor PGA Package Heat Sink Installation Application Note (Rev. C, 10/00)
- PID# 23828 AMD Athlon^{TM} Processor EMC Design Application Note (Rev. A, 5/00)
- PID# 23794 AMD Thermal, Mechanical, and Chassis Cooling Design Guide (Rev. B, 10/00)

Future requirements

- **AMD Athlon^{TM} Processor**
  - ? Organic pin grid array package
  - ? Organic ball grid array package for mobile
- **Hammer family**
  - ? SMT uPGA socket
  - ? Chassis mounting
  - ? Chassis designs to eliminate external-to-internal temperature rise